Crystal Ball® PRO

Getting Started Manual

Written, designed, and published in the United States of America.

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Welcome to Crystal Ball® Pro

Welcome to Crystal Ball Pro Version 4.0!

Crystal Ball Pro is a suite of forecasting and risk analysis tools that enhance spreadsheet modeling. In the same way that Crystal Ball first allowed many people to easily perform risk analysis with their spreadsheets, Crystal Ball Pro offers even more powerful ways to build and use spreadsheet models. Now you can combine optimization with your risk analysis, evaluate the effects of alternate decisions, address uncertainty and variability separately in a model, assess the reliability and accuracy of your forecasts, and automate these tasks with Visual Basic programs.

Who this program is for

Crystal Ball Pro is for anyone who uses spreadsheets to make critical decisions—from the business person analyzing the risk of new markets to the scientist evaluating experiments and hypotheses. With Crystal Ball Pro, you can forecast the range of results possible for your situation, and then make decisions that maximize the use of your resources, time, and money.

Crystal Ball Pro has been developed with a wide range of spreadsheet uses and users in mind. You don't need highly advanced statistical or computer knowledge to use Crystal Ball Pro to its full potential. All you need is a basic working knowledge of your personal computer and the ability to create an Excel spreadsheet model.

What you will need

To run Crystal Ball Pro, you will need the following:

- Microsoft Excel 95 (or later)
- Windows 95 or Windows NT 3.5.1 or later
- Personal computer with 80386/486/Pentium microprocessor and at least 16 MB RAM
- Hard disk drive with at least 12 MB free
- CD-ROM drive—4X or faster

- EGA, VGA, 8514/A, or Hercules graphics card or compatible video graphics adapter and monitor

Highly recommended option:

- Pentium I or II, 200 MHz or faster

Installing Crystal Ball Pro

Before installing Crystal Ball Pro, you must have Microsoft Excel installed and exit any other programs.

To install Crystal Ball Pro:

1. **Place the Crystal Ball Pro CD in your CD-ROM drive.**
2. **Either:**
   - For Windows 95 or Windows NT 4.0 or later, select Start > Run, enter d:setup (where d: is your CD-ROM drive), and click on OK.
   - For Windows NT 3.5.1, select File > Run, enter d:setup (where d: is your CD-ROM drive), and click on OK.

   The installation starts. The Welcome dialog appears.
3. **Read the Welcome dialog information.**
4. **Click on Next.**

   The User Information dialog appears.
5. **Enter your name, company, and Crystal Ball Pro registration number.**

   The registration number is on the back of the Crystal Ball Pro CD jewel case.
6. **Click on Next.**

   The Automatic Start Option dialog appears.
7. **Either:**
   - Start Crystal Ball automatically when you launch Excel by clicking on Yes.
   - Start Crystal Ball manually from Excel by clicking on No.

   You can change this setting later using Excel's Tools > Add-ins command.

8. **Click on Next.**

   The Locate Microsoft Excel dialog appears.

9. **Either:**

   - If the location of Microsoft Excel is correct, click on Next.
   - If the location of Microsoft Excel is incorrect, browse to find the correct location, and then click on Next.

   The Choose Destination Location dialog appears.

10. **Either:**

    - Accept the installation folder for Crystal Ball Pro by clicking on Next.
    - Change the installation folder for Crystal Ball Pro by clicking on Browse, changing the location, clicking on OK, and clicking on Next.

Crystal Ball Note: *You can install Crystal Ball Pro in any directory, on any drive where you have write permissions. It doesn't have to be under the Excel folder.*

11. **Click on Next.**

    The Select Components dialog appears. By default, all the Crystal Ball Pro components are selected.

12. **To *not* install a component, unselect it by clicking on a checkbox.**

    To select specific extenders to include, select Crystal Ball Extenders and click on Change.

13. **Click on Next.**

    The installation program copies the program files to the installation folder.

Crystal Ball Note: *If you are installing over a previous version of Crystal Ball, you might be prompted to overwrite existing read-only files. Click on Yes and continue.*

When the setup is complete, the program prompts you to view the Readme file.

14. Either:

- View the Readme file by clicking on Yes.

  The Readme file opens.

  The Readme file has the most recent information on changes to the documentation, compatibility issues, platform limitations, and technical support.

- Finish the installation without viewing the Readme file by clicking on No.

  The Setup Complete dialog appears.

15. Click on Finish.

How this manual is organized

The manual includes the following:

- **Chapter 1 - "Overview of Crystal Ball Pro"**

  This chapter briefly describes the different components of the Crystal Ball Pro suite and how they work together.

- **Chapter 2 - "Extenders"**

  This chapter describes advanced plug-in programs that extend the power and functionality of Crystal Ball.

- **Bibliography**

  A list of related publications.

- **Index**

  An alphabetical list of subjects and corresponding page numbers.

Additional resources

Decisioneering, Inc. offers these additional resources to increase the effectiveness with which you can use our product.

Technical support

If you have a technical support question or would like to comment on Crystal Ball Pro, there are a number of ways to reach Technical Support. See the accompanying Readme file for more information.

Consulting referral service

Decisioneering, Inc. provides referrals to individuals and companies alike. The primary focus of this service is to provide a clearinghouse for consultants in specific industries who can provide specialized services to the Crystal Ball and Crystal Ball Pro user community.

If you wish to learn more about this referral service, call 800-289-2550 Monday through Friday, between 9:00 A.M. and 5:00 P.M. Mountain Standard Time.

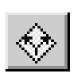
Conventions used in this manual

This manual uses the following conventions:

Text separated by > symbols means you select menu options in the sequence shown, starting from the left. The following example means that you select the Exit option from the File menu:

1. **Select File > Exit.**

Steps with attached icons mean you can click on the icon instead of manually selecting the menu options in the text. For example:



2. **Select Cell > Define Decision.**

Notes provide additional information, expanding on the text. There are five categories of notes:

Crystal Ball Note: *Notes that provide additional directions or information about using Crystal Ball.*

Extender Note: *Notes that provide additional directions or information about using the extenders.*

OptQuest Note: *Notes that provide additional directions or information about using OptQuest.*

Statistical Note: *Notes that provide additional information about statistics.*

Excel Note: *Notes that provide additional information about using the program suite with Microsoft Excel.*

Screen capture notes

All the screen captures in this document were taken in Excel 97 for Windows 95.

Also, due to round-off differences between various system configurations, you might notice slightly different calculated results than those shown in the examples.

Chapter 1

Overview of Crystal Ball Pro

In this chapter

- Overview of Crystal Ball Pro
- Crystal Ball
- OptQuest
- Extenders
- Developer Toolkit
- Spreadsheet analysis using Crystal Ball Pro

This chapter describes the Crystal Ball Pro suite of programs.

Crystal Ball Pro overview

The Crystal Ball Pro suite contains related components to enhance your spreadsheet analysis work. The different components of the suite are:

- Crystal Ball
- OptQuest for Crystal Ball
- Crystal Ball Extenders
- Crystal Ball Developer Kit

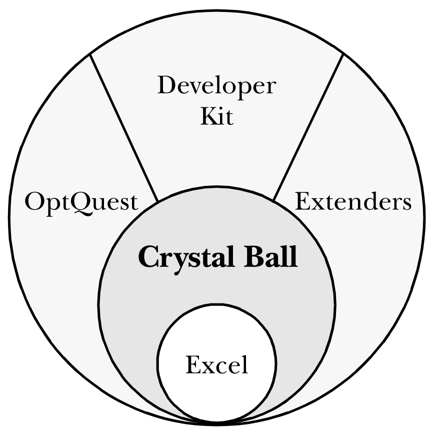


Figure 1.1 Crystal Ball Pro components

Crystal Ball

Crystal Ball is a user-friendly, graphically-oriented forecasting and risk analysis program that takes the uncertainty out of decision-making.

Crystal Ball works with your Excel spreadsheet to define the uncertainty in your model. Then, through a technique known as Monte Carlo simulation, Crystal Ball forecasts the entire range of results possible for a given situation. It also shows you confidence levels, so you will know the likelihood of any specific event taking place.

Crystal Ball is easy to learn and easy to use. Unlike other forecasting and risk analysis programs, you do not have to learn unfamiliar formats or special modeling languages. To get started, all you have to do is create a spreadsheet.

OptQuest for Crystal Ball

OptQuest enhances Crystal Ball by automatically searching for and finding optimal solutions to simulation models.

Simulation models by themselves can only give you a range of possible outcomes for any situation. They don't tell you how to control the variables in the model to achieve the best outcome.

You describe your optimization problem in OptQuest. Then, OptQuest invokes Crystal Ball to evaluate the simulation model for different sets of control variable values that maximize or minimize a predefined objective. OptQuest finds the right combination of values that produces the best results possible.

Like Crystal Ball, OptQuest is easy to learn and easy to use. It's wizard design leads you through the steps to optimize your model.

Crystal Ball Extenders

Extenders are Visual Basic programs that extend the functionality of Crystal Ball. They are:

Tornado Chart	Individually analyzes the impact of each model variable on a target outcome.
Decision Table	Evaluates the effects of alternate decisions in a simulation model.
Two-dimensional Simulation	Independently addresses uncertainty and variability using two-dimensional simulation.
Correlation Matrix	Rapidly defines and automates correlations of assumptions.
Bootstrap	Assesses the reliability and accuracy of forecast statistics.

Crystal Ball Developer Kit

The Crystal Ball Developer Kit (previously known as the Advanced Macro Interface or AMI) adds a new dimension to Crystal Ball. You can now completely automate and control Crystal Ball simulations from within a Visual Basic for Applications (VBA) program or any other language outside of Excel supporting OLE 2 automation.

The Crystal Ball Developer Kit describes the link between Crystal Ball and your program. It consists of a library of macro commands and functions that control nearly every aspect of Crystal Ball. Each copy of Crystal Ball comes enabled to use the Crystal Ball Developer Kit, so that programs you develop today can be run by other users as well.

Using Crystal Ball Pro for spreadsheet analysis

You can use the components of Crystal Ball Pro to analyze and maximize your spreadsheets in many ways. Below is a common scenario illustrating how all the components fit together for spreadsheet analysis.

After you create your spreadsheet in Excel, the first step in your analysis is determining which input variables in a model have the greatest impact on the outcome. This is called a sensitivity analysis, and you can use the Tornado Chart extender to perform one.

The Tornado Chart extender steps through each variable in your model, one at a time, testing values to determine how sensitive the outcome is to small changes. You will want to focus your analysis on the variables that result in large changes.

For the most important variables, describe the ones that are uncertain using probability distributions in Crystal Ball. Crystal Ball will forecast the entire range of results possible for the outcome variable using Monte Carlo simulation.

For important input variables that you can control, define these as decision variables in Crystal Ball. Then use OptQuest for Crystal Ball to determine what set of values will produce optimal results for your outcome. OptQuest can find optimal results even when other variables in the model are uncertain. For simple decision models or in models that contain only one or two dominant decision variables, use the Decision Table extender to get a portrait of how these variables alter the model results.

For more sophisticated analysis, use the two-dimensional simulation extender and the bootstrap extender. These extenders work together or independently to help you create more realistic and accurate simulation models.

Finally, use the Crystal Ball Developer Kit to automate many repetitive analysis tasks. With this kit you can create custom analysis and modeling applications without ever leaving your spreadsheet environment.

Chapter 2

Extenders

In this chapter

This chapter describes the Crystal Ball extenders:

- Tornado Chart
- Decision Table
- Two-dimensional Simulation
- Correlation Matrix
- Bootstrap

For each extender, there is a general description, an introduction tutorial, and a description of all dialogs, fields, and options.

Overview

This chapter describes the Crystal Ball Extenders. Extenders are Visual Basic programs that extend the functionality of Crystal Ball. They are:

Tornado Chart	Individually analyzes the impact of each model variable on a target outcome.
Decision Table	Evaluates the effects of alternate decisions in a simulation model.
Two-dimensional Simulation	Independently addresses uncertainty and variability using two-dimensional simulation.
Correlation Matrix	Rapidly defines and automates correlations of assumptions.
Bootstrap	Assesses the reliability and accuracy of forecast statistics.

This chapter describes each extender, provides a step-by-step example for using each extender, and describes the windows, dialogs, and options for each extender.

You can access the extenders under Excel's Tools menu.

Tornado Chart extender

The Tornado Chart extender measures the impact of each model variable one at a time on a target forecast. The extender displays the results in two ways:

- Tornado chart
- Spider chart

This method differs from the correlation-based method built into Crystal Ball in that this extender tests each assumption, decision variable, or cell independently. While analyzing one variable, the extender freezes the other variables at their base values. This measures the effect each variable has on the forecast cell while removing the effects of the other variables. This method is also known as "one-at-a-time perturbation" or "parametric analysis".

The Tornado Chart extender is useful for:

- Measuring the sensitivity of variables that you have defined in Crystal Ball.
- Quickly pre-screening the variables in your model to determine which ones are good candidates to define as assumptions or decision variables. You can do this by testing the precedent variables of any formula cell. See page 27 for more information on precedents.

Tornado chart

The extender tests the range of each variable at percentiles you specify and then calculates the value of the forecast at each point. The tornado chart illustrates the swing between the maximum and minimum forecast values for each variable, placing the variable that causes the largest swing at the top and the variable that causes the smallest swing at the bottom. The top variables have the most effect on the forecast, and the bottom variables have the least effect on the forecast.

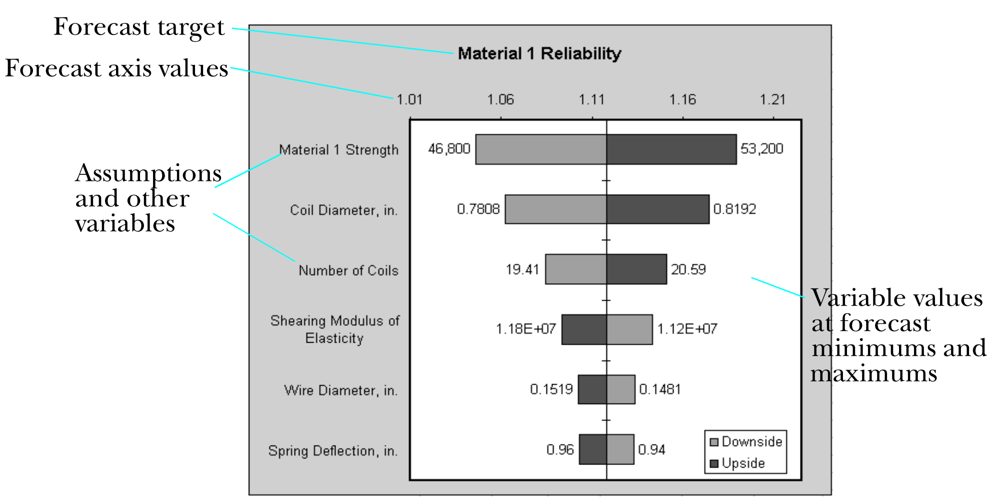


Figure 2.1 Tornado chart

The bars next to each variable represent the forecast value range across the variable tested, as discussed above. Next to the bars are the values of the variables that produced the greatest swing in the forecast values. The bar colors indicate the direction of the relationship between the variables and the forecast.

For variables that have a positive effect on the forecast, the upside of the variable (shown in blue) is to the right of the base case and the downside of the variable (shown in red) is to the left side of the base case. For variables that have a reverse relationship with the forecast, the bars are reversed.

When a variable's relationship with the forecast is not strictly increasing or decreasing, it is called non-monotonic. In other words, if the minimum or maximum values of the forecast range do not occur at the extreme end points of the testing range for the variable, the variable has a non-monotonic relationship with the forecast.

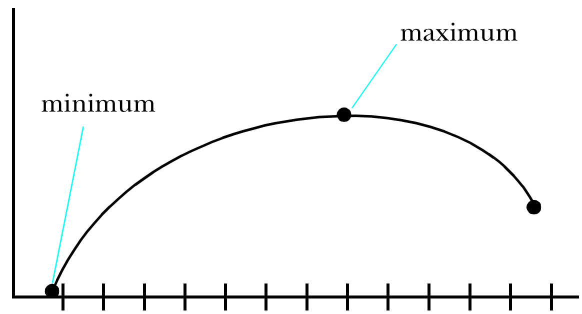


Figure 2.2 A non-monotonic variable

If one or more variables are non-monotonic, all the variable bars are the same color all the way across.

Spider chart

The spider chart illustrates the differences between the minimum and maximum forecast values by graphing a curve through all the variable values tested. Curves with steep slopes, positive or negative, indicate that those variables have a large effect on the forecast, while curves that are almost horizontal have little or no effect on the forecast. The slopes of the lines also indicate whether a positive change in the variable has a positive or negative effect on the forecast.

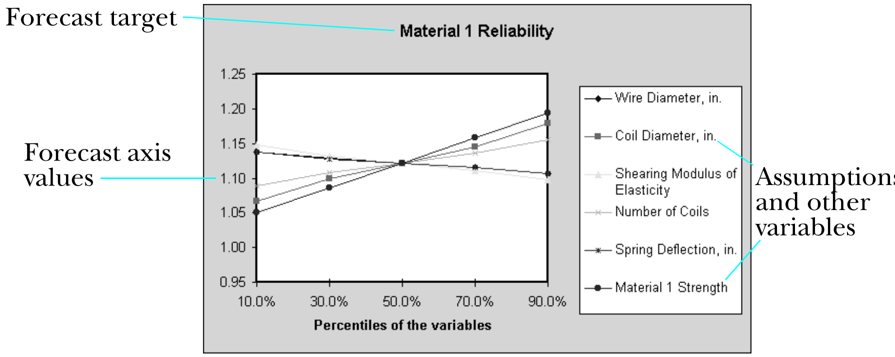


Figure 2.3 Spider chart

Extender Note: *There is a maximum of 250 variables for these charts.*

Tornado Chart example

In the Crystal Ball Examples folder there is a Reliable.xls spreadsheet you can use to experiment with the Tornado Chart extender. This spreadsheet model predicts the reliability of a spring using three different construction materials.

To run Tornado Chart:

1. **In Excel with Crystal Ball loaded, open the spreadsheet Reliable.xls.**

   If you have any other worksheets open, close them first, because the extender gathers all Crystal Ball definitions from all open worksheets.

2. **Select Tools > CB Tornado Chart.**

   The Specify Target (Step 1 Of 3) dialog appears. All of the forecasts from Reliable.xls appear in the list.

3. **Select the "Material 1 Reliability" forecast.**

4. **Click on Next.**

   The Specify Input Variables (Step 2 Of 3) dialog appears.

5. **Click on Add Assumptions.**

6. **Remove Material 2 Strength and Material 3 Strength.**

    a. **Select an assumption to remove.**

    b. **Click on Remove.**

    c. **Repeat steps 6a and 6b for the second assumption to remove.**

    The last two assumptions have no impact on the target forecast. If you leave them in the list, they will appear in the charts even though they are unrelated to the target forecast.

7. **Click on Next.**

    The Specify Options (Step 3 Of 3) dialog appears.

8. **Make sure the following options are set:**

    - Testing range is set to 10% to 90%
    - Testing points is set to 5
    - For Base Case is set to Use Existing Cell Values
    - Tornado Method is set to Percentiles Of The Variables
    - Both Tornado Chart and Spider Chart are selected

9. **Click on Start.**

    The extender creates the tornado and spider charts on their own workbooks.

Interpreting the results

In this example, six assumptions are listed in the tornado chart. The first assumption, Material 1 Strength, has the highest sensitivity ranking and is the most important. A researcher running this model would investigate this assumption further in the hopes of reducing its uncertainty, and therefore its effect on the target forecast, Material 1 Reliability.

The last two assumptions, Wire Diameter and Spring Deflection, are the least influential assumptions. Since their effects on the Material 1 Reliability are very small, you might ignore their uncertainty or eliminate them from the spreadsheet.

Caveats

While tornado and spider charts are very useful, there are some caveats:

- Since the extender tests each variable independently of the others, the extender doesn't consider correlations defined between the variables.
- The results shown in the tornado and spider charts depend significantly on the particular base case used for the variables. To confirm the accuracy of the results, run the extender multiple times with different base cases.

  This characteristic makes the one-at-a-time perturbation method less robust than the correlation-based method built into Crystal Ball's sensitivity chart. Hence, the sensitivity chart is preferable, since it computes sensitivity by sampling the variables all together while a simulation is running.

Tornado Chart dialogs

Specify Target (Step 1 Of 3) dialog

The Specify Target dialog lets you choose which forecast or formula cell to target.

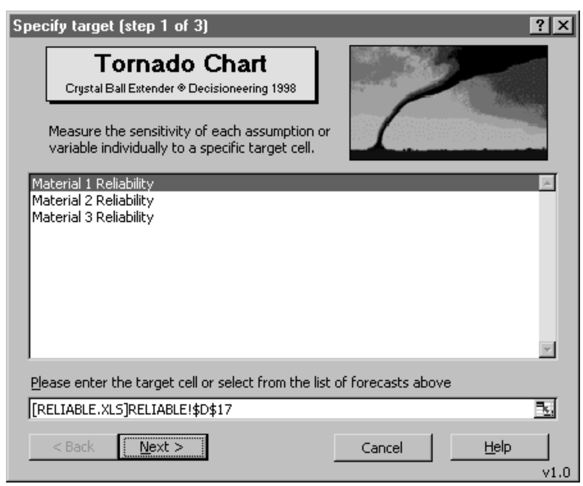


Figure 2.4 Specify Target dialog for Tornado Chart

The fields and buttons in this dialog are:

Forecast List — Lists all the forecast cells in all open spreadsheets. When you select a forecast from the list, its cell information automatically appears in the Enter Target Cell field.

The first forecast is selected by default.

Enter Target Cell — Describes the cell location of the selected forecast or formula. If you select a forecast from the list above, the cell information automatically appears in this field.

You can use this field to select a formula cell instead of a forecast.

Next — Opens the Specify Input Variables dialog.

Specify Input Variables (Step 2 Of 3) dialog

This dialog lets you select the assumptions, decision variables, and precedents to include in the tornado and spider charts.

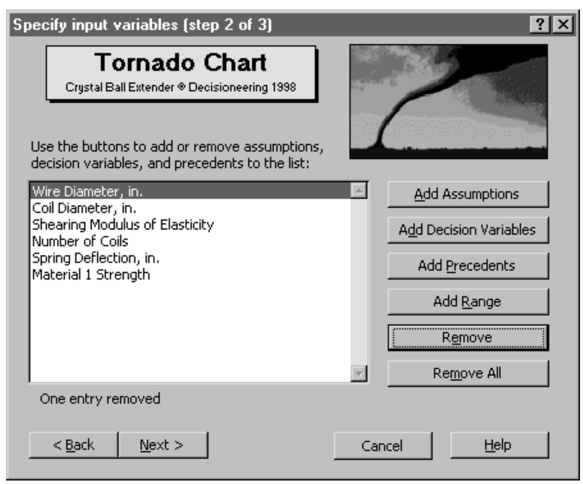


Figure 2.5 Specify Input Variables dialog for Tornado Chart

You can include any value cell in your tornado chart calculations. However, the cells are usually:

assumptions
: Cells defined as assumptions in Crystal Ball.

  For more information about assumptions, see your *Crystal Ball User Manual*.

decision variables
: Cells defined as decision variables in Crystal Ball.

  For more information about defining decision variables, see your *OptQuest User Manual*.

precedents
: All cells *within the active spreadsheet* that are referenced as part of the formula or a sub-formula of the target cell.

Extender Note: *Precedents for this extender are handled differently than standard Excel precedents in that they cannot trace beyond the active spreadsheet. Therefore, you can only use precedents on the active spreadsheet as input variables.*

The field and buttons in this dialog are:

Input Variable List
: Lists all the variables selected for the tornado and spider charts.

Add Assumptions
: Adds all assumptions from all open worksheets to the input variable list.

Add Decision Variables
: Adds all decision variables from all open worksheets to the input variable list.

Add Precedents
: Adds all precedents of the target cell from all open worksheets to the input variable list.

Add Range
: Lets you select a range of cells from the open worksheet to add to the input variable list. If you click this button, an Input dialog appears asking you to enter a cell range or to select a range of cells from the spreadsheet. You must click on OK to accept the selected range.

Remove	This button removes the selected variable from the input variable list.
Remove All	Removes all of the items from the input variable list.
Back	Returns to the Specify Target dialog.
Next	Opens the Specify Options dialog.

Specify Options (Step 3 Of 3) dialog

This dialog lets you set options that control the extender. The groups of options in this dialog are:

- Tornado Method
- Tornado Input
- Tornado Output

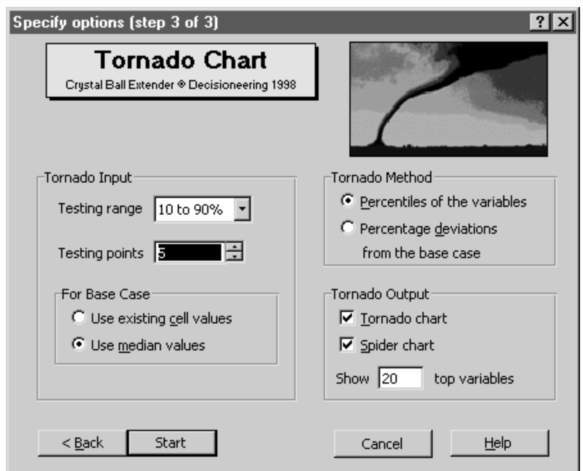


Figure 2.6 Specify Options dialog for Tornado Chart

The buttons in this dialog are:

Back	Returns to the Specify Input Variables dialog.
Start	Starts the extender, generating the tornado and spider charts.

Tornado Method options

The Tornado Method options in this dialog are:

Percentiles Of The Variables
: Indicates that the extender should test the variables using percentiles of the assumption distributions or percentiles of the decision variable ranges.

  This is the default.

Percentage Deviations From The Base Case
: Indicates that the extender should test the variables using small changes that are specified percentages away from the base case.

  This is the only option available if you selected variables other than assumptions or decision variables.

Extender Note: *The extender treats discrete decision variables as continuous for this second method.*

Tornado Input options

The Tornado Input options are:

Testing Range
: Defines the range in which the extender samples the variables. The choices are either: the percentile range (if the tornado method is Percentiles Of The Variables) or the percent from the base case (if the tornado method is Percentage Deviations From The Base Case).

  The default is 10% to 90% percentiles or -10% to 10% deviation.

Testing Points
: Defines how many values to test in the testing range. The testing points are evenly distributed across the testing range. Testing more points than just end points detects non-monotonic variable relationships.

  The default is five testing points.

For Base Case	Specifies whether to define the base case as either the existing cell values or the median values of the variables. If the tornado is based on a percentage deviation, only the cell values option is available. The default is the median cell values.

Tornado Output options

The Tornado Output options are:

Tornado Chart	Generates a tornado chart showing the sensitivity of the variables using range bars.
Spider Chart	Generates a spider chart showing the sensitivity of the variables using sloping curves.
Show Top Variables	Indicates how many variables to include in the tornado charts if there are a lot of variables. The charts can only clearly show about 20 variables.

Decision Table extender

Decision variables are values that you can control, such as how much to charge for a product or how many wells to drill. But, in situations with uncertainty, it is not always obvious what effect changing a decision variable can have on the forecast results.

The Decision Table extender runs multiple simulations to test different values for one or two decision variables. The extender tests values across the range of the decision variables and puts the results in a table that you can analyze using Crystal Ball forecast, trend, or overlay charts.

The Decision Table extender is useful for investigating how changes in the values of a few decision variable affect the forecast results. For models that contain many decision variables (more than 10), or where you are trying to optimize the forecast results, use OptQuest for Crystal Ball. See your *OptQuest User Manual* for more information.

Table 1: Comparison and contrast between the Decision Table extender and OptQuest.

	Decision Table extender	***OptQuest***
Process	Runs multiple Crystal Ball simulations for different values of decision variables	
Results	All displayed in a table	Only displays the best solutions.
Optimization	No	Yes
Number of variables	One or two	Unlimited
Variable range	Small	Small to large

Decision Table example

In the Crystal Ball Examples folder there is an Oil Field Development.xls spreadsheet you can use to experiment with the Decision Table extender. This spreadsheet model predicts how to best develop a new oil field by selecting the optimal number of wells to drill, rate of oil production, and size of the refinery to build that will maximize the net present value of the field.

To run Decision Table:

1. **In Excel with Crystal Ball loaded, open the spreadsheet Oil Field Development.xls.**
2. **In the Run > Run Preferences dialog, set Random Number Generation to use the Same Sequence Of Random Numbers and a seed value of 999.**

   When using this extender, use this option to make the resulting simulations comparable.
3. **Select Tools > CB Decision Table.**

   The Specify Target dialog appears.
4. **Select the NPV forecast.**

5. **Click on Next.**

   The Select One Or Two Decisions dialog appears.

6. **Move Wells To Drill and Facility Size to the Chosen Decision Variables list.**

   a. **Select Wells To Drill in the Available Decision Variables field.**

   b. **Click on >>.**

   c. **Repeat steps 6a and 6b for the Facility Size.**

7. **Click on Next.**

   The Specify Options dialog appears.

8. **Set the following options:**

   - Number of values to test for Wells to Drill is 6
   - Number of values to test for Facility Size is 7
   - Number of trials per simulation is 500

9. **Click on Start.**

   The extender runs a simulation for each combination of decision variable values. It compiles the results in a table of forecast cells indexed by the decision variables.

Interpreting the results

For this example, the Decision Table extender ran 42 simulations, one for each combination of wells to drill and facility sizes. The simulation that resulted in the best mean NPV was the combination of 12 wells and a facility size of 150 mbd.

Trend Chart Overlay Chart Forecast Charts	Wells to drill (2)	Wells to drill (12)	Wells to drill (21)	Wells to drill (31)	Wells to drill (40)	Wells to drill (50)	
Facility size (50.00)	55.57	151.76	60.38	-42.56	-135.42	-238.75	1
Facility size (100.00)	-4.43	290.87	221.00	120.42	28.11	-74.86	2
Facility size (150.00)	-54.43	300.75	287.61	195.56	104.80	2.40	3
Facility size (200.00)	-94.43	265.22	282.50	201.56	112.68	11.07	4
Facility size (250.00)	-124.43	235.22	256.58	179.80	91.70	-9.73	5
Facility size (300.00)	-144.43	215.22	236.73	160.49	72.40	-29.04	6
Facility size (350.00)	-154.43	205.22	226.73	150.49	62.40	-39.04	7
	1	2	3	4	5	6	

Figure 2.7 Decision table for Oil Field Development results

To view one or more of the forecasts in the decision table, select the cells and click on Forecast Charts. To compare one or more forecasts on the same chart, select the cells and click on Trend Chart or Overlay Chart.

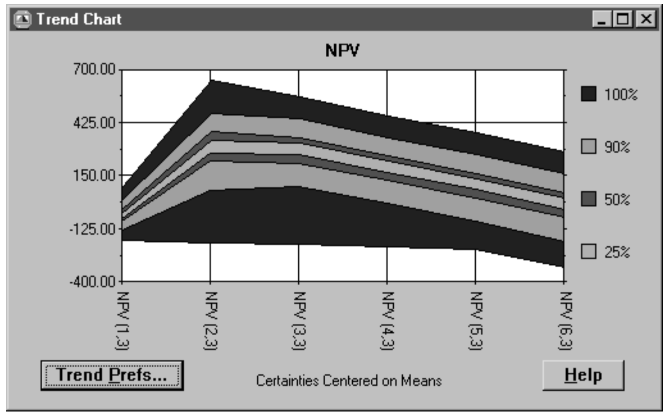


Figure 2.8 Trend chart of 150 mbd forecasts

You can create the above trend chart by selecting all the forecast cells in the Facility Size (150.00) row of the results table and clicking on Trend Chart. This chart shows that the forecast with the highest mean NPV also has the largest uncertainty compared to other forecasts with smaller NPVs of the same facility size. This indicates a higher risk that you could avoid with a different number of wells (although the lower risk is accompanied with a lower NPV).

Decision Table dialogs

Specify Target (Step 1 Of 3) dialog

The Specify Target dialog lets you choose which forecast to target.

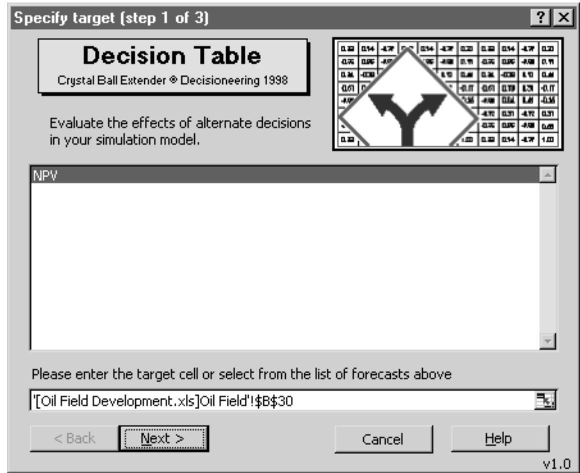


Figure 2.9 Specify Target dialog for Decision Table

The fields and buttons in this dialog are:

Forecast List — Lists all the forecast cells in all open spreadsheets. When you select a forecast from the list, its cell information automatically appears in the Enter Target Cell field.

The first forecast is selected by default.

Enter Target Cell — Describes the cell location of the selected forecast or formula. If you select a forecast from the list above, the cell information automatically appears in this field.

You can use this field to select a formula cell instead of a forecast.

Next — Opens the Select One Or Two Decisions dialog.

Select One Or Two Decisions (Step 2 Of 3) dialog

This dialog lets you select one or two decision variables to explore.

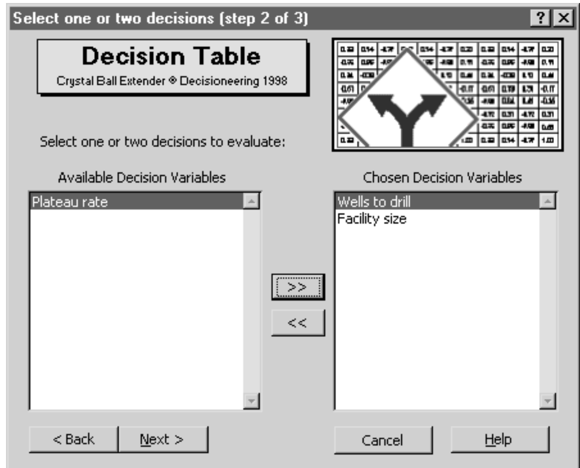


Figure 2.10 Select One Or Two Decisions dialog for Decision Table

The fields and buttons in this dialog are:

Available Decision Variables	Lists all the defined decision variables in the open spreadsheets.
Chosen Decision Variables	Lists one or two decision variables that the extender will test different values for.
>>	Moves the selected decision variable in the Available Decision Variables list to the Chosen Decision Variables list.
<<	Moves the selected decision variable in the Chosen Decision Variables list to the Available Decision Variables list.
Back	Returns to the Specify Target dialog.
Next	Opens the Specify Options dialog.

Specify Options (Step 3 Of 3) dialog

The Specify Options dialog lets you select options to control how the extender works.

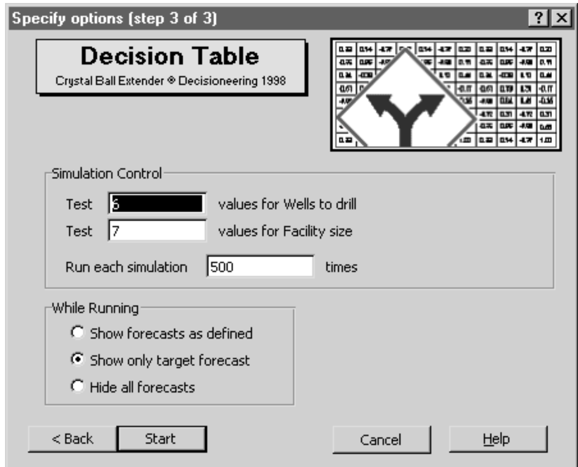


Figure 2.11 Specify Options dialog for Decision Table

The Simulation Control options in this dialog are:

Number Of Test Values For Each Decision Variable

Sets the number of values the extender will test. The extender distributes the number of values evenly across the defined decision variable range.

If you have one decision variable, the extender runs a simulation for each test value. For two decision variables, the extender runs a simulation for each combination of values, i.e., the product of the two numbers of test values.

The default is 10 values for continuous decision variables or for discrete decision variables with a step size greater than 40.

Trials Per Simulation
: Sets the number of trials to run for each simulation.

  The default is the number set in the Crystal Ball run preferences.

The While Running options are:

Show Forecasts As Defined
: Displays a forecast chart for each defined forecast during the simulation.

Show Only Target Forecast
: Displays only the forecast chart for the target forecast during the simulation.

Hide All Forecasts
: Displays no forecast charts during the simulation.

The buttons are:

Back
: Returns to the Select One Or Two Decisions dialog.

Start
: Runs the extender.

Two-dimensional Simulation extender

Risk analysts must often consider two sources of variation in their models:

uncertainty
: Assumptions that are uncertain because you have insufficient information about a true, but unknown, value. Examples of uncertainty include the reserve size of an oil field and the prime interest rate in 12 months. You can describe an uncertainty assumption with a probability distribution.

  Theoretically, you can eliminate uncertainty by gathering more information. Practically, information can be missing because you haven't gathered it or because it is too costly to gather.

variability — Assumptions that change because they describe a population with different values. Examples of variability include the individual body weights in a population or the daily number of products sold over a year. You can describe a variability assumption with a frequency distribution (or approximate it with a probability distribution).

Variability is inherent in the system, and you cannot eliminate it by gathering more information.

For many types of risk assessments, it is important to clearly distinguish between uncertainty and variability.[1] Separating these concepts in a simulation lets you more accurately detect the variation in a forecast due to lack of knowledge and the variation caused by natural variability in a measurement or population. In the same way that a one-dimensional simulation is generally better than single-point estimates for showing the true probability of risk, a two-dimensional simulation is generally better than a one-dimensional simulation for characterizing risk.

The Two-dimensional Simulation extender runs an outer loop to simulate the uncertainty values, and then freezes the uncertainty values while it runs an inner loop (of the whole model) to simulate the variability. This process repeats for some small number of outer simulations, providing a portrait of how the forecast distribution varies due to the uncertainty.

The primary output of this process is a chart depicting a series of cumulative frequency distributions. You can interpret this chart as the range of possible risk curves associated with a population.

Extender Note: *When using this extender, set the Seed Value option in the Crystal Ball Run Preferences dialog so that the resulting simulations are more comparable.*

1. Hoffman, F. O. and J. S. Hammonds. "Propagation of uncertainty in risk assessments: The need to distinguish between uncertainty due to lack of knowledge and uncertainty due to variability," *Risk Analysis*, vol. 14, no. 5. pp 707-712, 1994.

Two-dimensional Simulation example

In the Crystal Ball Examples folder there is a Toxic.xls spreadsheet you can use to experiment with the Two-dimensional Simulation extender. This spreadsheet model predicts the cancer risk to the population from a toxic waste site. This spreadsheet has two variability assumptions and two uncertainty assumptions.

To run the Two-dimensional Simulation extender:

1. **In Excel with Crystal Ball loaded, open the spreadsheet Toxic.xls.**
2. **Select Tools > CB 2D Simulation.**

   The Specify Target dialog appears.
3. **Select the Risk Assessment forecast.**
4. **Click on Next.**

   The Specify Assumptions dialog appears.
5. **Move Body Weight and Volume Of Water Per Day to the Variability list.**
   a. **Select Body Weight.**
   b. **Click on >>.**
   c. **Repeat steps 5a and 5b for Volume Of Water Per Day.**

   This separates the assumptions into the two types: uncertainty and variability.
6. **Click on Next.**

   The Specify Options dialog appears.
7. **Set the following options.**
   - Outer simulation runs set to 100
   - Inner simulation runs set to 1,000
8. **Click on Start.**

   The simulations start. The extender first single-steps one trial to generate a new set of values for the uncertainty assumptions. Then it freezes these assumptions and runs a simulation for the variability assumptions in the inner loop.

   The extender retrieves the Crystal Ball forecast information after each inner loop runs. The extender then resets the simulation and repeats the process until the outer loop has run for the specified number of simulations.

Interpreting the results

The results of the simulations appear in a table containing the forecast means, the uncertainty assumption values, and the statistics (including percentiles) of the forecast distribution for each simulation.

	A	B	C	D	E	F	G	H	I	J	K
1		Risk Assessment(1)	Risk Assessment(2)	Risk Assessment(3)	Risk Assessment(4)	Risk Assessment(5)	Risk Assessment(6)	Risk Assessment(7)	Risk Assessment(8)	Risk Assessment(9)	Risk Assessment(10)
2		3.94E-05	5.27E-05	5.29E-05	5.67E-05	5.88E-05	5.98E-05	6.09E-05	6.22E-05	6.31E-05	6.36E-05
3	**Assumptions:**										
4	Concentration of Contaminant in Water	101.24	92.78	111.69	116.55	102.70	102.96	93.57	115.01	103.43	110.48
5	CPF	1.3E-02	1.9E-02	1.6E-02	1.6E-02	1.9E-02	1.9E-02	2.2E-02	1.8E-02	2.0E-02	1.9E-02
6											
7	**Statistics:**										
8	Mean	3.94E-05	5.27E-05	5.29E-05	5.67E-05	5.88E-05	5.98E-05	6.09E-05	6.22E-05	6.31E-05	6.36E-05
9	Median	3.78E-05	5.05E-05	5.06E-05	5.43E-05	5.63E-05	5.73E-05	5.84E-05	5.96E-05	6.05E-05	6.09E-05
10	Standard Deviation	1.91E-05	2.55E-05	2.56E-05	2.75E-05	2.85E-05	2.90E-05	2.95E-05	3.02E-05	3.06E-05	3.08E-05
11	Variance	3.65E-10	6.52E-10	6.55E-10	7.55E-10	8.10E-10	8.40E-10	8.71E-10	9.09E-10	9.35E-10	9.49E-10
12	Skewness	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45
13	Kurtosis	3.13	3.13	3.13	3.13	3.13	3.13	3.13	3.13	3.13	3.13
14	Coeff. of Variability	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48
15	Minimum	4.78E-07	6.39E-07	6.41E-07	6.88E-07	7.12E-07	7.25E-07	7.39E-07	7.55E-07	7.65E-07	7.71E-07
16	Maximum	1.16E-04	1.55E-04	1.56E-04	1.67E-04	1.73E-04	1.76E-04	1.79E-04	1.83E-04	1.86E-04	1.87E-04
17	Range	1.16E-04	1.55E-04	1.55E-04	1.66E-04	1.72E-04	1.75E-04	1.79E-04	1.83E-04	1.85E-04	1.87E-04
18											
19	**Percentiles:**										
20	5%-tile	1.04E-05	1.39E-05	1.40E-05	1.50E-05	1.55E-05	1.58E-05	1.61E-05	1.65E-05	1.67E-05	1.68E-05
21	10%-tile	1.56E-05	2.08E-05	2.09E-05	2.24E-05	2.32E-05	2.36E-05	2.41E-05	2.46E-05	2.49E-05	2.51E-05
22	15%-tile	1.93E-05	2.58E-05	2.59E-05	2.78E-05	2.88E-05	2.93E-05	2.98E-05	3.05E-05	3.09E-05	3.11E-05

Figure 2.12 Two-dimensional Simulation results table

The extender also graphs the results of the two-dimensional simulations on an overlay chart and a trend chart. The overlay chart shows the risk curves for the simulations for different sets of uncertainty assumption values.

In the chart below, most of the risk curves are clustered densely toward the center while a few outlier curves are scattered to the right, showing the small probability of having a much greater risk.

Statistical Note: *In risk analysis literature, the curves are often called the alternate realizations of the population risk assessment.*

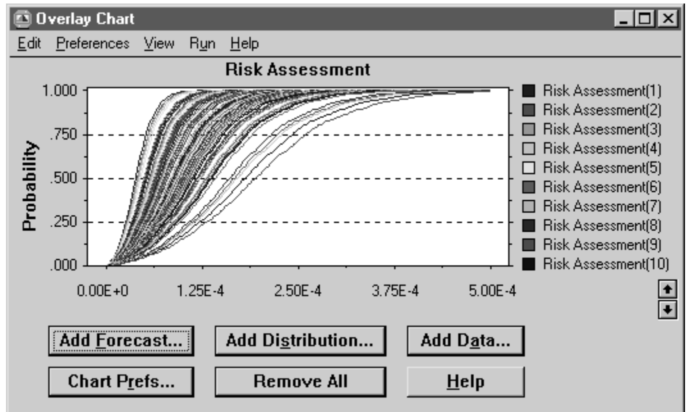


Figure 2.13 Overlay chart of risk curves

Another helpful output is a trend chart depicting certainty bands for the percentiles of the risk curves. The band width shows the amount of uncertainty at each percentile level for all the distributions.

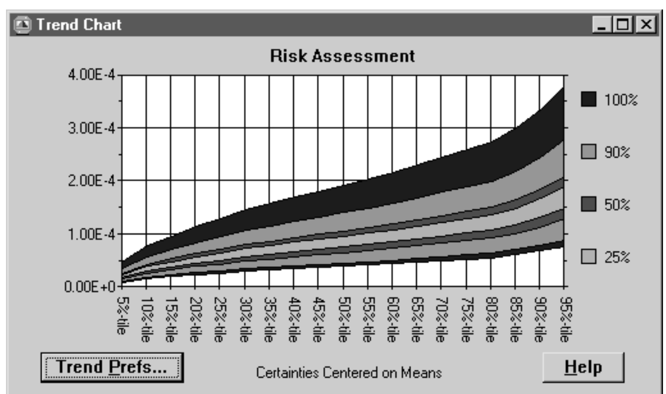


Figure 2.14 Trend chart of certainty bands

You can focus in on a particular percentile level, such as the 95th percentile, by viewing the statistics of the 95th percentile forecast.

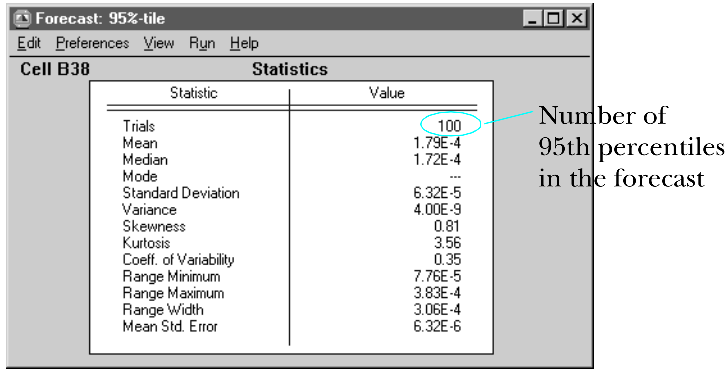


Figure 2.15 95th percentiles forecast statistics

Compare the results of the two-dimensional simulation to a one-dimensional simulation (with both uncertainty and variability co-mingling together) of the same risk model. The mean of the 95th percentiles, 1.79E-4, is lower than the 95th percentile risk of the one-dimensional simulation shown below at 2.03E-4. This indicates the tendency of the one-dimensional simulation results to overestimate the population risk, especially for highly skewed distributions.

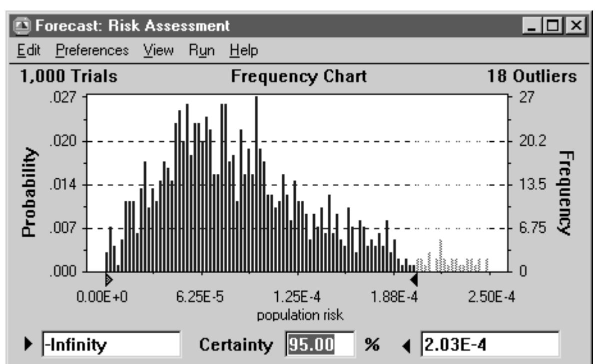


Figure 2.16 Forecast chart for one-dimensional simulation

Second-order assumptions

Some assumptions contain elements of both uncertainty and variability. For instance, an assumption might describe the distribution of body weights in a population, but the parameters of the distribution might be uncertain. These types of assumptions are called second-order assumptions (also, second-order random variables).[2] You can model these types of assumptions in Crystal Ball by placing the uncertain parameters of the distribution in separate cells and defining these cells as assumptions. You then link the parameters of the variability assumption to the uncertainty assumptions using cell references.

To illustrate this for the Toxic spreadsheet:

1. **Enter the values 70 and 10 into cells G4 and G5, respectively.**

   These are the mean and standard deviation of the Body Weight assumption in cell C4, which is defined as a normal distribution.

2. **Define an assumption for cell G4 using a normal distribution with a mean of 70 and a standard deviation of 2.**

3. **Define an assumption for cell G5 using a normal distribution with a mean of 10 and a standard deviation of 1.**

4. **Enter references to these cells in the Body Weight assumption.**

   When you run the extender for second-order assumptions, the uncertainty of the assumptions' parameters is modeled in the outer simulation, and the distribution of the assumption itself is modeled (for different sets of parameters) in the inner simulation.

Crystal Ball Note: *Often, the parameters of assumptions are correlated. For example, you would correlate a higher mean with a higher standard deviation or a lower mean with a lower standard deviation. Defining correlation coefficients between parameter distributions can increase the accuracy of your two-dimensional simulation. When data is available, as in sample body weights of a population, you can use the Bootstrap extender to estimate the sampling distributions of the parameters and the correlations between them.*

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2. Burmaster, David E., and Andrew M. Wilson. "An Introduction to Second-Order Random Variables in Human Health Risk Assessments," *Human and Ecological Risk Assessment: vol. 2, no. 4.* pp 892-919, 1996.

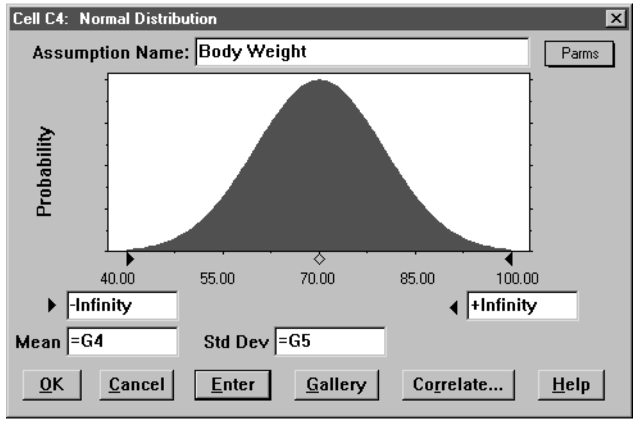


Figure 2.17 Assumption using cell references for the mean and standard deviation

Two-dimensional Simulation dialogs

Specify Target (Step 1 Of 3) dialog

The Specify Target dialog lets you choose which forecast to target.

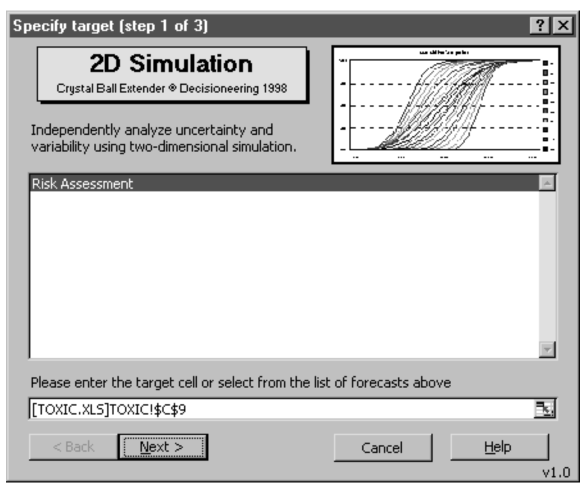


Figure 2.18 Specify Target dialog for Two-dimensional Simulation

The fields and buttons in this dialog are:

Forecast List — Lists all the forecast cells in all open spreadsheets. When you select a forecast from the list, its cell information automatically appears in the Enter Target Cell field.

The first forecast is selected by default.

Enter Target Cell — Describes the cell location of the selected forecast or formula. If you select a forecast from the list above, the cell information automatically appears in this field.

You can use this field to select a formula cell instead of a forecast.

Next — Opens the Specify Assumptions dialog.

Specify Assumptions (Step 2 Of 3) dialog

This dialog separates the assumptions into uncertainty assumptions and variability assumptions. All the assumptions from all open worksheets start in the Uncertainty list by default. You must have at least one assumption of each type.

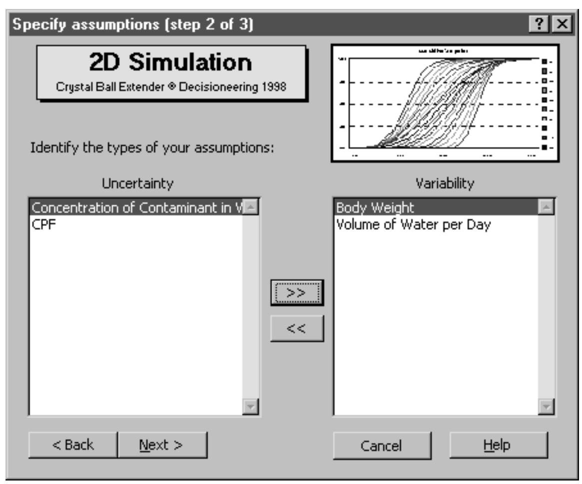


Figure 2.19 Specify Assumptions dialog for Two-dimensional Simulation

When you save your spreadsheet model, the extender remembers the assumption types for the next time you run the extender.

The fields and buttons in this dialog are:

>>	Moves any selected assumptions in the Uncertainty list to the Variability list.
<<	Moves any selected assumptions in the Variability list to the Uncertainty list.
Back	Returns to the Specify Target dialog.
Next	Opens the Specify Options dialog.

Specify Options (Step 3 Of 3) dialog

This dialog lets you set the options that control how the extender runs.

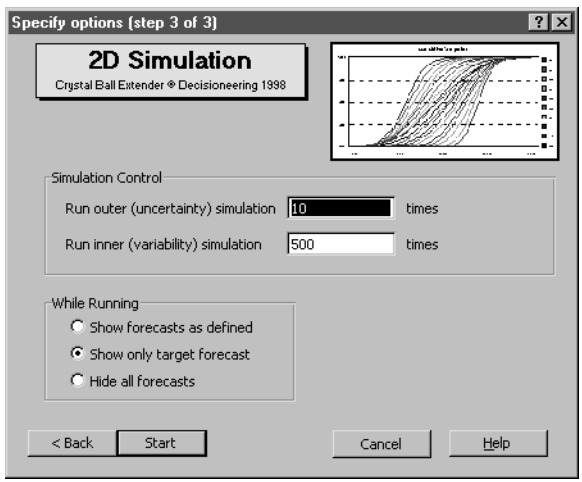


Figure 2.20 Specify Options dialog for Two-dimensional Simulation

The Simulation Control options in this dialog are:

Outer simulation runs

Sets the number of times the extender simulates the uncertain assumptions in the outer loop. These values are then frozen during the inner simulations.

The default is 10.

Inner simulation runs
: Sets the number of times the extender simulates the variability assumptions in the inner loop.

  The default is the number of trials set in the Crystal Ball run preferences.

The While Running options are:

Show Forecasts As Defined
: Displays a forecast chart for each defined forecast during the simulation.

Show Only Target Forecast
: Displays only the forecast chart for the target forecast during the simulation.

Hide All Forecasts
: Displays no forecast charts during the simulation.

The buttons are:

Back — Returns to the Specify Assumptions dialog.

Start — Runs the extender.

Correlation Matrix extender

Correlations

When the values of two variables depend on each other in any way, you should correlate them to increase the accuracy of your simulation's forecast results.

There are two types of correlations:

positive correlation
: Indicates that two assumptions increase or decrease together. The price of gasoline and shipping costs increase and decrease together.

negative correlation
Indicates that an increase in one assumption results in a decrease in the other assumption. The more items you buy from a particular vendor, the lower the unit cost.

The correlation coefficient range is -1 to 1, where 0 indicates no correlation. The closer the coefficient is to ±1, the stronger the relationship between the assumptions. You should never use a coefficient of ±1; represent relationships this closely correlated with formulas in the spreadsheet model.

Correlation matrix

In Crystal Ball, you enter correlations one at a time using the Correlation dialog. Instead of manually entering the correlations this way, you can use the Correlation Matrix extender to define a matrix of correlations between assumptions in one simple step. This saves time and effort when building your spreadsheet model, especially for models with many correlated assumptions.

The correlation matrix is either an upper or lower triangular matrix with ones along the diagonal. When entering coefficients, think of the matrix as a multiplication table. If you follow one assumption along its horizontal row and the second along its vertical column, the value in the cell where they meet is their correlation coefficient.

	Assumption 1	Assumption 2	Assumption 3
Assumption 1	1.000		
Assumption 2		1.000	
Assumption 3			1.000

Figure 2.21 Correlation matrix

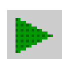
If you enter inconsistent correlations, Crystal Ball tries to adjust the correlations so they don't conflict. For more information on inconsistent correlations, see your *Crystal Ball User Manual*.

Correlation Matrix example

In the Crystal Ball Examples folder there is a Portfolio Allocation.xls spreadsheet you can use to experiment with the Correlation Matrix extender. This spreadsheet calculates the total expected return for an investment model. In this example, you will run a simulation without correlations, and then add the correlations and rerun the simulation for comparison.

To run Correlation Matrix:

1. **In Excel with Crystal Ball loaded, open the spreadsheet Portfolio Allocation.xls.**
2. **Set the following options in the Run > Run Preferences dialog.**
   - Maximum Number Of Trials Per Simulation set to 500
   - Random Number Generation set to use the Same Sequence Of Random Numbers and a seed value of 999



3. **Run a simulation by selecting Run > Start.**

   The forecast statistics for the simulation are shown below.

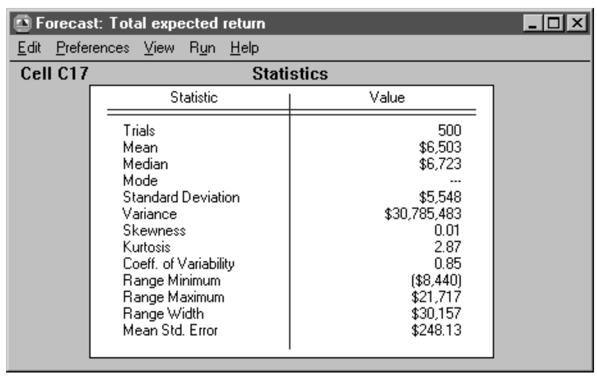


Figure 2.22 Uncorrelated simulation statistics

4. **Select Tools > CB Correlation Matrix.**

   The Select Assumptions dialog appears.

5. **Include all the assumptions in the correlation matrix by moving all the assumptions from the Available Assumptions field to the Selected Assumptions field by either:**

   - Double-clicking on each assumption to move.
   - Selecting each assumption to move and clicking on >> to move it.
   - Making an extended selection using the <Shift> or <Ctrl> keys.

6. **Click on Next.**

   The Specify Options dialog appears.

7. **Select the options:**

   - Location Of Matrix set to Create A Temporary Matrix On A New Worksheet
   - Orientation set to Upper Triangular Matrix

8. **Click on Start.**

   The extender creates a temporary matrix in a new workbook.

9. **Enter the following correlation coefficients into the matrix.**

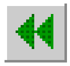
Load the matrix	Money Market fund	Income fund	Growth and Income fund	Aggressive Growth fund
Money Market fund	1.000	0.200	0.100	0.100
Income fund		1.000	0.300	0.200
Growth and Income fund			1.000	0.500
Aggressive Growth fund				1.000

Extender Note: *Leaving a cell blank is not the same as entering a zero. Values that are not specified in the matrix will be "filled in" with estimates of appropriate values when the simulation runs.*

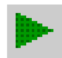
10. **Click on Load The Matrix.**

    The extender loads the correlation coefficients from the matrix into your Crystal Ball model.

Extender Note: *If a Matrix Successfully Loaded message doesn't appear, press <Tab> or <Return> to exit the current cell and then click on Load The Matrix again.*

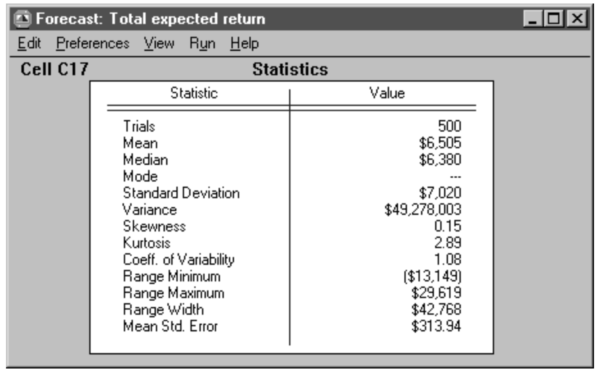


11. **Reset the simulation.**



12. **Rerun the simulation.**

The forecast statistics for the correlated simulation is shown below.



Statistic	Value
Trials	500
Mean	$6,505
Median	$6,380
Mode	---
Standard Deviation	$7,020
Variance	$49,278,003
Skewness	0.15
Kurtosis	2.89
Coeff. of Variability	1.08
Range Minimum	($13,149)
Range Maximum	$29,619
Range Width	$42,768
Mean Std. Error	$313.94

Figure 2.23 Correlated simulation statistics

The standard deviation is now much higher than the original simulation due to the correlations. The original model without the correlations ignored this risk factor and its effects.

Correlation Matrix dialogs

Select Assumptions (Step 1 Of 2) dialog

The Select Assumptions dialog lets you select which assumptions to use in the correlation matrix.

You must select at least two assumptions. There is a practical limit of about 100 total correlated assumptions per model. If you have more than 100 assumptions, either eliminate very small correlations, or replace assumptions that have correlation coefficients very close to one with formulas in your spreadsheet.

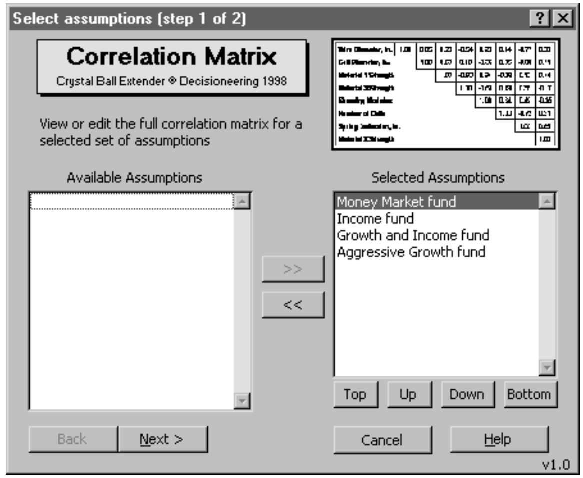


Figure 2.24 Select Assumptions dialog for Correlation Matrix

The fields and buttons in this dialog are:

Available Assumptions

Lists all the assumptions defined in the active workbook. To move an assumption into the Selected Assumptions list, either double-click on an assumption or select an assumption and click on >>. You can also make an extended selection using the <Shift> or <Ctrl> keys.

By default, all assumptions start in the Available Assumptions list.

Selected Assumptions

Lists the assumptions selected for inclusion in the matrix. To move an assumption into the Available Assumption list, either double-click on an assumption or select an assumption and click on <<. You can also make an extended selection using the <Shift> or <Ctrl> keys.

By default, no assumptions are in this list.

Top

Moves one or more selected assumptions in the Selected Assumptions list to the top of the list.

Bottom	Moves one or more selected assumptions in the Selected Assumptions list to the bottom of the list.
Up	Moves one or more selected assumptions in the Selected Assumptions list up one position.
Down	Moves one or more selected assumptions in the Selected Assumptions list down one position.
Next	Opens the Specify Options dialog for defining correlation matrix options.

Specify Options (Step 2 Of 2) dialog

This dialog lets you set options for the matrix.

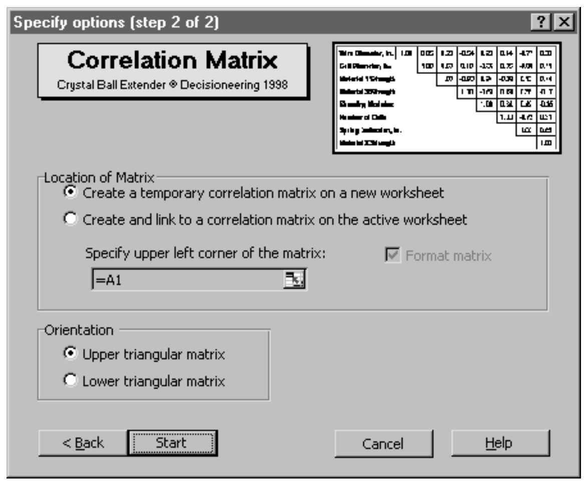


Figure 2.25 Specify Options dialog for Correlation Matrix

There are two sets of options in this dialog (described below):

- Location Of Matrix
- Orientation

This dialog also has the following buttons:

Back	Returns you to the Select Assumptions dialog.

Start — Creates the correlation matrix according to the options you specify.

Location Of Matrix options

The Location Of Matrix options lets you select whether to create the correlation matrix on the active worksheet or on a new worksheet. The options in this dialog are:

Create A Temporary Correlation Matrix On A New Worksheet
: Creates the matrix on a new worksheet. Use this option if you don't want to permanently alter your spreadsheet.

  After filling in the matrix, click on Load The Matrix to enter the coefficients into the model.

  This is the default matrix location.

Create And Link To A Correlation Matrix On The Active Worksheet
: Creates the matrix on the active worksheet and links it with cell references, so if you change the cells, the correlations update automatically. Select this option to embed the correlation matrix in your model.

  If you select this option, you must indicate where to put the matrix in the model using the Specify Upper Left Corner option.

Specify Upper Left Corner
: Lets you select the origin cell for the top left corner of the matrix by either entering the cell reference in the field or clicking on the cell in your worksheet.

  This option is only available if you select to create the matrix on the worksheet.

Format Matrix — Adds borders and headings, and changes column widths to make the correlation matrix more readable.

  This option is only available if you select to create the matrix on the worksheet. This option is on by default.

Orientation options

The Orientation options let you select whether to make the correlation matrix an upper triangular or a lower triangular matrix.

Upper Triangular Matrix
: Creates the matrix with cells to fill in above the diagonal. This is the default.

Lower Triangular Matrix
: Creates the matrix with cells to fill in below the diagonal.

Bootstrap extender

Bootstrap is a simple technique that estimates the reliability or accuracy of forecast statistics or other sample data. Classical methods used in the past relied on mathematical formulas to describe the accuracy of sample statistics. These methods assume that the distribution of a sample statistic approaches a normal distribution, making the calculation of the statistic's standard error or confidence interval relatively easy. However, when a statistic's sampling distribution is not normally distributed or easily found, these classical methods are difficult to use or are invalid.

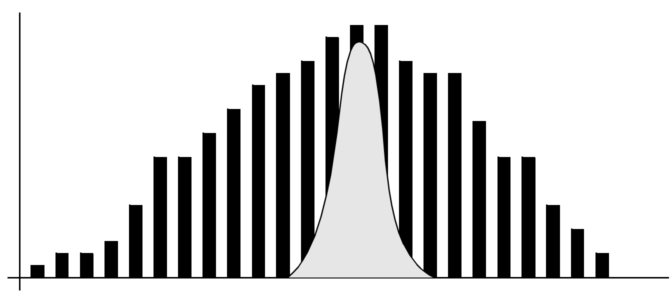


Figure 2.26 Sampling distribution of a mean statistic

In contrast, bootstrapping analyzes sample statistics empirically by repeatedly sampling the data and creating distributions of the different statistics from each sampling. The term bootstrap comes from the saying, "to pull oneself up by one's own bootstraps," since this method uses the distribution of statistics themselves to analyze the statistics' accuracy.

There are two bootstrap methods available with this extender:

One-simulation method
: Simulates the model data once (creating the original sample), and then repeatedly resamples those simulation trials (the original sample values). Resampling creates a new sample from the original sample **with replacement**. It then creates a distribution of the statistics calculated from each resample.

: This method assumes only that the original simulation data accurately portrays the true forecast distribution, which is likely if the sample is large enough. This method isn't as accurate as the multiple-simulation method, but it takes significantly less time to run.

Glossary Term:
with replacement— Returns the selected value to the sample before selecting another value, letting the selector possibly reselect the same value.

Multiple-simulation method
: Repeatedly simulates the model, and then creates a distribution of the statistics from each simulation.

: This method is more accurate than the one-simulation method, but it might take a prohibitive amount of time.

Extender Note: *When you use the multiple-simulation method, the extender temporarily turns off the Use Same Seed Value option.*

Statistical Note: *In statistics literature, the one-simulation method is also called the non-parametric bootstrap, and the multi-simulation method is also called the parametric bootstrap.*

Since the bootstrap technique doesn't assume that the sampling distribution is normally distributed, you can use it to estimate the sampling distribution of any statistic, even an unconventional one such as the minimum or maximum end point of a forecast.

You can also easily estimate complex statistics, such as the correlation coefficient of two data sets, or combinations of statistics, such as the ratio of a mean to a variance.

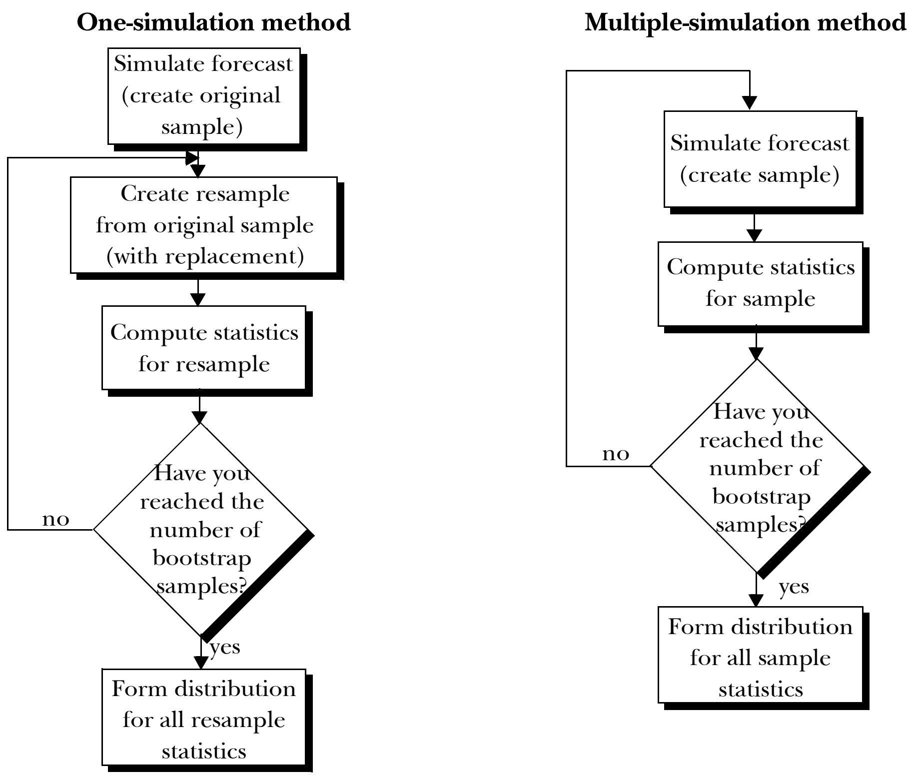


Figure 2.27 Comparison of one-simulation and multiple-simulation bootstrap methods

Statistical Note: *To estimate the accuracy of Latin Hypercube statistics, you must use the multiple-simulation method.*

Bootstrap example

In the Crystal Ball Examples folder there is a Futura.xls spreadsheet you can use to experiment with the Bootstrap extender. This spreadsheet model forecasts the profit and loss for an apartment complex.

To run Bootstrap:

1. **In Excel with Crystal Ball loaded, open the spreadsheet Futura.xls.**
2. **Select Tools > CB Bootstrap.**

   The Specify Target dialog appears.
3. **Set the target by selecting Profit Or Loss from the forecast list.**
4. **Click on Next.**

   The Specify Options (Step 2 of 3) dialog appears.
5. **Make sure the one-simulation method and the statistics options are selected.**
6. **Click on Next.**

   The Specify Options (Step 3 of 3) dialog appears.
7. **Set the options:**

   Bootstrap samples
   200

   Trials per sample
   500

8. **Click on Start.**

The bootstrap extender displays a forecast chart of the distributions for each statistic and creates a spreadsheet summarizing the data.

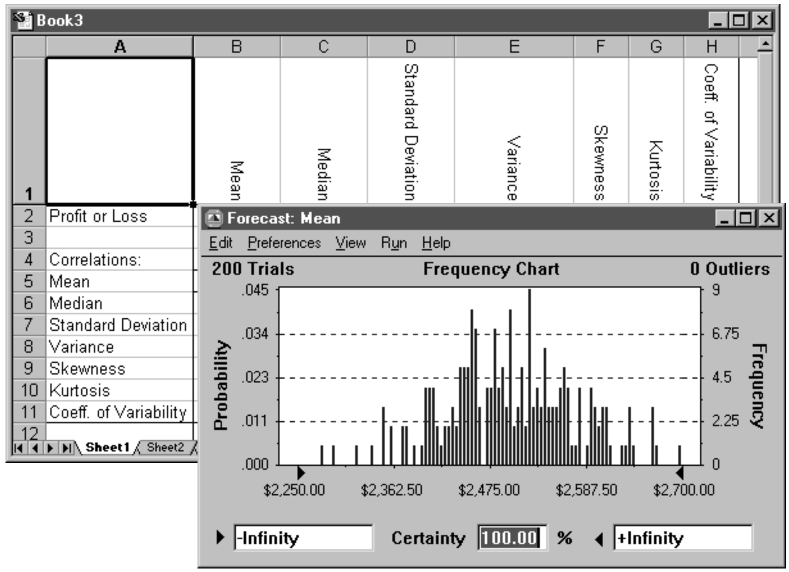


Figure 2.28 Bootstrap example results

Interpreting the results

The Bootstrap extender displays sampling distributions in forecast charts for the following statistics:

- Mean
- Median
- Standard deviation
- Variance
- Skewness
- Kurtosis
- Coefficient of variability

When you use the multiple-simulation method, the extender also displays sampling distributions for these statistics:

- Range minimum
- Range maximum
- Range width

For percentiles, the Bootstrap extender displays the percentile sampling distributions on the overlay and trend charts. To display the individual percentile forecast charts select Run > Forecast Windows.

The forecast charts visually indicate the accuracy of each statistic. A narrow and symmetrical distribution is better than a wide and skewed distribution.

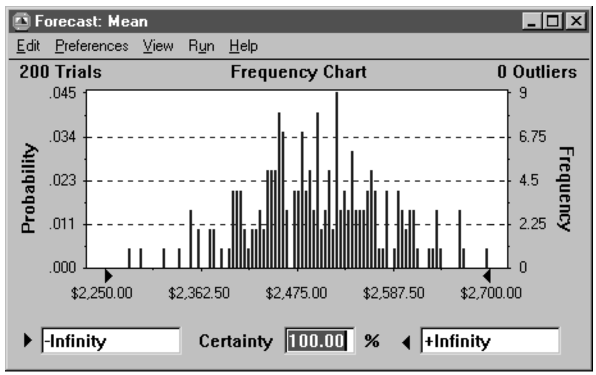
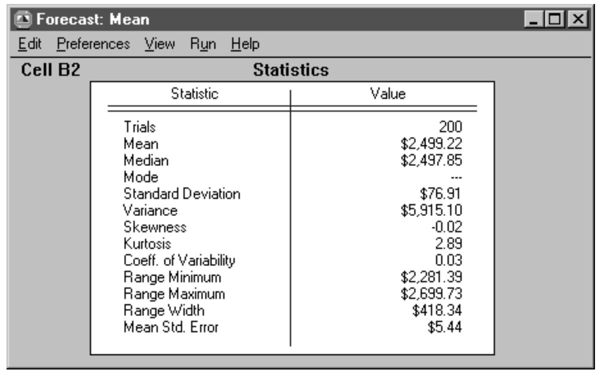


Figure 2.29 Bootstrap forecast chart of mean

The statistic view further lets you analyze the statistics' sampling distribution. If the standard deviation (standard error of the statistic) or coefficient of variability is very large, the statistic might not be reliable and might require more trials. This example has a relatively low standard error and coefficient of variability, so the forecast mean is an accurate estimate of the actual mean.



Statistic	Value
Trials	200
Mean	$2,499.22
Median	$2,497.85
Mode	---
Standard Deviation	$76.91
Variance	$5,915.10
Skewness	-0.02
Kurtosis	2.89
Coeff. of Variability	0.03
Range Minimum	$2,281.39
Range Maximum	$2,699.73
Range Width	$418.34
Mean Std. Error	$5.44

Figure 2.30 Bootstrap forecast statistics of mean

The results workbook has a correlation matrix showing the correlations between the various statistics. High correlation between certain statistics, such as between the mean and the standard deviation, usually indicates a highly skewed distribution.

You can also use the Bootstrap extender to analyze the distribution of percentiles, but you should run at least 1,000 bootstrap samples and 1,000 trials per sample to obtain good sampling distributions for these statistics.[3]

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3. Efron, Bradley, and Robert J. Tibshirani. *Monographs on Statistics and Applied Probability, vol. 57: An Introduction to the Bootstrap.* New York: Chapman & Hall, 1993.

Bootstrap dialogs

Specify Target (Step 1 Of 3) dialog

The Specify Target dialog lets you analyze the statistics of a specified forecast, cell, or cell range.

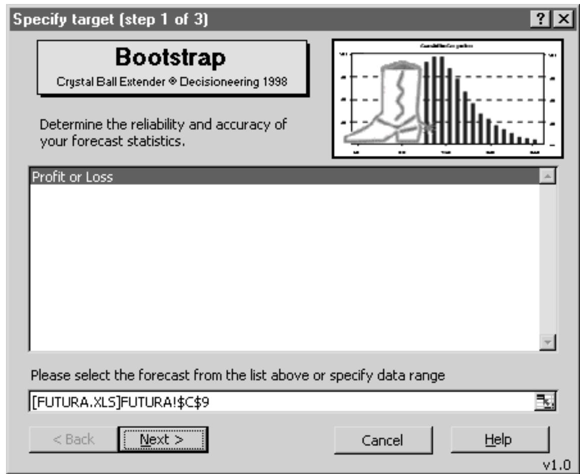

Figure 2.31 Specify Target dialog for Bootstrap

The fields for this dialog are:

Forecast List — Lists all the forecast cells in all open spreadsheets. When you select a forecast from the list, its cell information automatically appears in the Enter Target Cell field.

The first forecast is selected by default.

Enter Target Cell — Describes the cell location of the selected forecast or formula. If you select a forecast from the list above, the cell information automatically appears in this field.

You can use this field to select a formula cell instead of a forecast.

Next — Opens the next dialog for defining extender options.

Specify Options (Step 2 Of 3) dialog

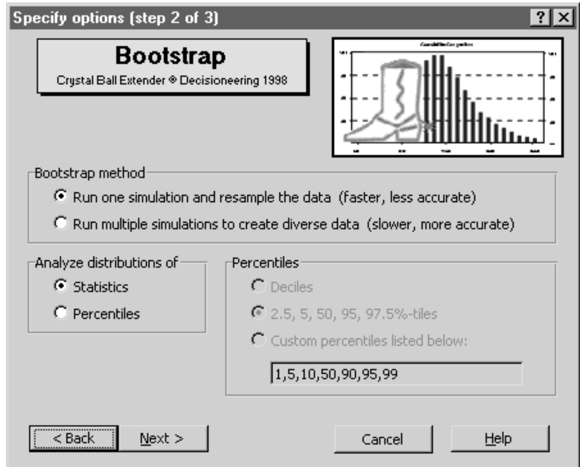

Figure 2.32 First Specify Options dialog for Bootstrap

This first options dialog has the following options, fields, and buttons:

Bootstrap Method

Selects whether to use the one-simulation or multiple-simulation bootstrap method. For more information on these two methods, see “Bootstrap extender” on page 55.

The default is the one-simulation method.

Analyze Distributions Of

Selects whether to analyze distributions of statistics or percentiles. If you select Percentiles, you must complete the Percentiles options.

The default is Statistics.

Percentiles

Selects which target percentiles to analyze. You can select either: deciles (the 10, 20, 30, 40, 50, 60, 70, 80, and 90 percentiles); 2, 5, 50, 90, and 97.5 percentiles; or a custom list of percentiles you enter in the field. A custom list can have up to 10 percentiles (between 0 and 100, exclusive) separated by commas.

Back	Opens the Specify Target dialog for specifying a target.
Next	Opens the next dialog for defining more extender options.

Specify Options (Step 3 Of 3) dialog

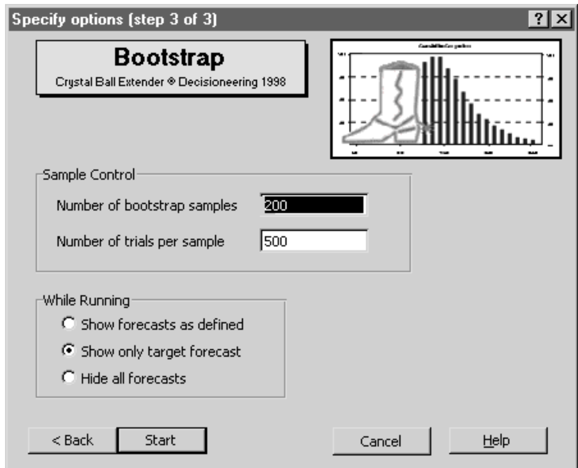

Figure 2.33 Second Specify Options dialog for Bootstrap

This second options dialog has the following options, fields, and buttons.

Sample Control	Sets the number of bootstrap samples and the number of trials per sample. The default bootstrap samples is 200, and the default number of trials is the number set in the Crystal Ball Run Preferences dialog.
While Running	Lets you select what forecasts to show while you are running the extender. You can view all the defined forecasts, only the target forecast, or none of the forecasts.
Back	Opens the previous dialog for defining other extender options.
Start	Runs the Bootstrap extender.

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- Tornado charts and sensitivity analysis
- Two-dimensional simulation
- Bootstrap

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Credits

Crystal Ball Pro Getting Started Manual

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